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THE ADAPTATION OF AERIAL METHODS TO THE FOREST LOSS SURVEY

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TABLE OF CONTENTS

INTRODUCTION 1

PREVIOUS FOREST INSECT AIR SURVEYS 2

Use of Airplanes in the West 2

Use of Autogiros on the East Coast 4

OUTLINE OF AIR SURVEY METHODS. 5

Spotting Methods 5

Photographic Methods 8

VERTICAL PHOTOGRAPHS FOR FOREST INSECT LOSS SURVEYS. 12

Equipment Requirements 12

The Camera 12

The Plane. 13

Preflight Preparations 14

Ground Preparations. 14

Scale. 15

Altitude of Flight 16

The Flight Map 17

Flight Requirements for Best Photographs 17

Procedure for Taking Pictures. 17

OBLIQUE PHOTOGRAPHS FOR FOREST INSECT LOSS SURVEYS 18

PROPOSALS FOR TESTING AIRCRAFT FOR FOREST INSECT LOSS SURVEYS.19

Objectives 20

Areas. 20

Time of Survey 20

THE ADAPTATION OF AERIAL METHODS TO THE FOREST LOSS SURVEY

INTRODUCTION

Within the past two decades, aerial methods of mapping have been adapted to meet many needs. Aerial photographs have been used for forest mapping and timber surveys (Andrews and Trorey, 1933; Foster, 1934; Kreuger, 1941; Rothery, 1935), laying out woods operations (Wilcox, 1938), fuel type mapping (Lee, 1941), and for many other purposes. The mapping by ground methods of forested areas, difficult of access from the ground, is slow and expensive, often requiring manpower not commensurate with the needs of the survey. The aerial camera and the airplane have proven to be the answer to this problem (U. S. Forest Service, 1935). The solution to a problem of a similar nature faces the Forest Insect Laboratories serving the western region. The problem is the forest insect loss survey. Under the present survey system, ground methods only are utilized to obtain loss data. If methods can be developed for sampling insect-caused losses from the air, it is possible that better estimates could be obtained for those areas now being surveyed by ground methods, and that coverage could be extended to outlying areas not now being sampled.

The real justification for using aircraft for forest insect loss surveys lies in the need for a more rapid and efficient system for obtaining loss records. Present methods of getting this information by means of reconnaissance, road strips and counts, and plot cruises are tedious and time-consuming. They are, furthermore, far from adequate, albeit they may afford the best records obtainable with the facilities and personnel available. Hall (1942) has shown that from the statistical standpoint the survey system used in the California region is subject to considerable error due to the limitations of ground samples now in use. However, the cost of establishing a large enough series of samples to provide statistically correct estimates would be almost prohibitive if ground methods were used. The trial of aerial methods is justified by the promise of securing better loss estimates within the territory served by the western laboratories.

PREVIOUS FOREST INSECT AIR SURVEYS

The idea of detecting insect damage in forested areas from the air has been broached periodically since the advent of airplanes for fire patrol. Aerial reconnaissance flights have been made on several occasions since early in the twenties. Planes have been used in forest insect control work for dusting or spraying woodland. (Keen, 1931; Potts, 1939). The chief difficulty experienced in past air survey trials in this region has resulted from the inability of entomologists to have access to the plane for a long enough time to determine the most advantageous use of it. The planes have been supplied by other agencies under conditions which have permitted the entomologists little more than a ride over the forest. In short, it has not been possible to plan a test program that would definitely answer whether or not aerial methods could be used for the measurement of losses.

Use of Airplanes in the West

The earliest attempt to survey forest insect damage from the air was made by Miller (1926) in 1925. A photographic and an observation plane were supplied by the Army Air Service, and flights were made over the Sierra National Forest. Aerial photographs were taken of the Cascadel and Bass Lake units at an elevation of about 9,000 feet above the average ground level. It was found that individual trees could be distinguished on the photographs, but that it was not always possible to discern the insect-killed trees. A ground check showed that 90 percent of the insect-killed timber, still retaining discolored foliage, registered in the pictures. However, the scale of these pictures was really too small to be satisfactory, and without a ground check it would have been impossible to estimate the number of dead trees from the photographs alone.

The following year a test was made of aerial spotting and sample plot photography under eastside conditions. Through arrangements with the Forest Service, a forest fire patrol contract plane was assigned to the Modoc National Forest for a two-day flight over the Happy Camp-Lava Beds area. Flights were made on September 25 and 28, 1927, with Captain Boggs piloting the plane and Keen (1927) making the observations and taking both vertical and oblique photographs with a 4 x 5 aerial hand camera from over the side of the open cockpit. Two dozen pictures were taken mostly from an elevation of about 2,000 feet above the forest.

The plan for this experiment as recalled by Keen was two-fold. First, to see what could be done in general reconnaissance by spotting red-top trees on a map and by oblique photographs using panchromatic film and a color filter; and secondly, to test the use of vertical photographs as a sampling method. For this latter test, ground preparations consisted of laying out two 40-acre plots with the corners marked by a flag of newspapers laid on the ground and held down by rocks. On each of the plots all beetle-killed trees, both red-tops and current loss, were tabulated and mapped, so that a comparison could be made between the number identified in the photographs and the number actually on the ground.

On the first day's flight, general reconnaissance methods were tested. With a half-inch to the mile scale map mounted on a drawing board and held in his lap, Keen attempted to jot down the number and location of red-top trees as seen from the plane. While a splendid view was had of the forest and the general distribution of infested trees, it soon became apparent that it was impossible to count these trees or spot them on the map. Red-top trees were everywhere - conspicuous when near at hand, but fading into the distance and into the green forest as this stretched off to the horizon. There was no place to begin or end the tree count or to be sure where to spot them on the map. The oblique photographs were of more value, but involved the same difficulties; namely, decreasing visibility in the distance and no line of demarcation for a strip count.

On the second day's flight, the plane was flown over the previously marked 40-acre plots. When directly over the plot, at a signal from Keen, the pilot stalled the plane by pulling up the nose and shutting off the motor. The camera had to be held over and away from the side of the fuselage to avoid vibration. This required unfastening the safety belt and kneeling in the seat with one arm around a guy wire. It did not add to the photographer's comfort when the pilot tipped the plane sideways so that the view directly downward was totally unobstructed.

It had been planned to take verticals at several elevations above the forest so as to determine what scale would take in the 40-acre plots and be of greatest usefulness as photographic samples. However, the plane did not have sufficient power to fly higher than 2,000 feet above the forest, so other flight levels were not flown. At the 2,000 foot level, the 4 x 5 prints covered a ground area approximately 10 acres which would have been satisfactory for sampling purposes provided a large series of pictures could have been taken at random over the area. On this scale red-top trees showed plainly when taken with an "A" filter (Figure 3B). For sampling a large area, it appeared that verticals taking in a larger ground area would have been preferable.

This test of pine beetle surveying from the air showed that it had definite possibilities and also limitations. It could be of great value for general reconnaissance of unfamiliar areas, but spotting and counts made by eye were impractical in large areas of unbroken forest. Sampling by vertical photographs was shown to be entirely practical for red-top surveys, but that additional tests were needed to work out many details as to most satisfactory flight elevations and map scale, comparison with ground conditions and relative costs.

Miller (1931) and Salman attempted a reconnaisance flight in an open cockpit Forest Service biplane over the Tahoe, Eastern Plumas, and Lassen National Forests. Rough air conditions, poor visibility and lack of familiarity of the observers with the terrain made the survey quite unsatisfactory. Since only four hours of contract-flying time were available the attempt was not repeated. During the same year the cooperation of entomologists at the Portland, Oregon, Forest Insect Laboratory was enlisted in an airplane dusting project undertaken by the State of Washington and the Weyerhaeuser Timber Company to control the hemlock looper in Southwestern Washington. (Goodyear, 1931; Keen, 1931). An aerial survey was made prior to treatment, and a series of vertical photographs were taken which were converted into a mosaic map covering about 40 square miles. The pictures proved disappointing in that the defoliated trees were indistinguishable from those that were not attacked. The project proved more successful in its effects on the hemlock looper infestation, an estimated average reduction of 45 percent in the defoliation having been secured.

In 1941 G. R. Struble and Ranger Munhall (see Miller, 1941) flew over the Mariposa District of the Sierra National Forest in a two-seated cabin plane. The flight was made at an elevation of 2,000 feet above the average ground level. The observers made independent counts of the insect-killed trees; one tallied trees seen, and the other spotted trees on a map. A comparison of the two methods showed that one observer had seen half again as many trees as had the other. In spite of good visibility, ability to maintain the desired elevation and good working conditions, the speed of the plane (80-90 miles per hour) was too great to be satisfactory.

Use of Autogiros on the East Coast

Potts (1939) in 1936 was the first to test the autogiro for forest insect control from the air. He found it practical to spray woodland plots from this type of craft in order to control the gypsy moth. A series of 10-acre test plots, stocked with hardwoods varying from 15 to 40 feet in height, were treated with concentrated sprays. The plot corners were marked with orange flags flown from bamboo poles, and a row of white flags was placed down the center of each plot to

mark the course of flight for the pilot. The autogiro was flown at speeds ranging from 39-50 miles per hour at an elevation of 20 to 35 feet above the forest canopy. Potts concluded that control of the gypsy moth could be effected with equipment of this kind.

A trial of the autogiro for scouting southern pine beetle infestations near Franklin, Virginia, was made in 1939 by Craighead and Wilford (1939). The giro was flown at speeds ranging from 35 to 40 miles per hour, 100 to 300 feet above the ground. It was found that infested trees could be distinctly seen and located on a geological survey map during the course of the flight. Where group infestations occurred, in which the individual trees could not be distinguished in straight flight, the number of trees in the group could be discerned by circling the giro around the group at a reduced speed. No ground check of the accuracy of the aerial survey was made, but the report of the flight indicated that the autogiro offered considerable promise as a means for obtaining forest insect loss information.

OUTLINE OF AIR SURVEY METHODS

There are two general methods that presumably could be adapted to an aerial survey of loss. One method would be to count and tally, or spot on a map, the dead trees that could be seen in flights over the forest. The other method would be to take aerial photographs of samples of the stand on a large enough scale to permit the estimation of timber loss from the pictures. Some of these methods have been tried, but with the possible exception of the reconnaisance none has as yet been adequately tested as to its particular merits.

Spotting Methods

In an aerial survey three variations of spotting methods, currently used in ground surveys, can be tried. They are (1) reconnaisance, (2) line survey, (3) strip sampling, and plot sampling. The reconnaisance consists of a flight over the area for the purpose of detecting insect outbreaks, and perhaps getting a general impression of the loss conditions. It affords qualitative information, or at the most very crude quantitative data, for it is almost impossible to convert reconnaisance counts to a loss per acre figure. Past attempts to obtain quantitative estimates by tallying loss by watersheds, in the course of reconnaisance flights, have not proven to be particularly successful.

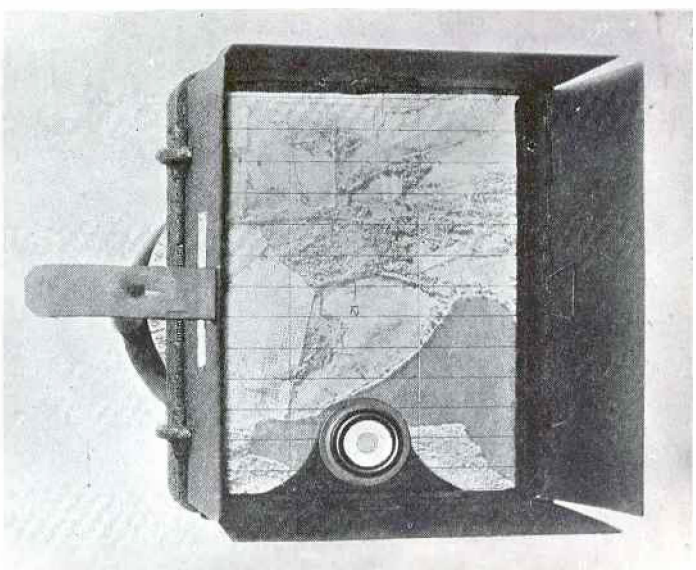
Theoretically, at least, it should be possible to make line, strip, or sample plot counts from a slow moving craft like an autogiro in much the same manner that road strips or counts and sample plot surveys are made from the ground. Surveys of this type have not been attempted from the air thus far. The reason is probably that the aircraft used in past tests have been too fast to permit flying at a low

enough elevation, and at a slow enough speed to observe and tally the trees. Furthermore, no method has been proposed thus far for limiting the view of the observer to that portion of the ground actually being sampled, even if the plane did meet these requirements.

Assuming that the autogiro was satisfactory with regard to its flight speed and ability to fly at a low elevation, there are several methods that could be tried for obtaining loss data on a sample basis. (For the time-being, consider that the ground is perfectly level, and that the plane can be kept on a fixed course.) One method would be a line count. In explanation, if the course of the plane were considered to be a line stretching from one boundary of the survey unit to the other, and if all insect-killed trees touching that line were counted, a sample area would be obtained having a length corresponding to the flight distance; and a width equivalent to the average crown width. To apply this theory it would be necessary to have in the plane an arrangement to trace an imaginary line over the forest canopy as the ship moved over it. A cross hair or pointer should suffice. A second method would be to employ a lensless viewer having an opening of fixed dimensions from which the observer's eye could be held at a fixed distance. At a known height above the ground level, a sample strip could be viewed which would be proportional in dimensions to the size of the opening in the viewer. A third method that might be tested would be to use instruments with a lens system, such as field glasses, or something similar to the Fairchild aerial view finder (Figure 1). The dimensions of the field of view could be calculated, if the focal length of the lens and elevation were known. The tally of insect trees could then be easily converted to an area basis. One of the drawbacks of instruments requiring a lens system is that the intensity of illumination on the subject may be cut to the point where it would be impossible to distinguish the trees.

Another sampling methodthat could be tried would be to make counts of insect-killed trees on small regular or irregular-shaped plots, having permanent boundaries. The boundaries could be either artificial or natural, preferably the latter. The plots could then be surveyed from the air in much the same manner as they are at present cruised from the ground, except that it would not be possible to mark the individual trees. The spotting of the trees on a plot map might be maintained. Sample plots would lend themselves to segregation by timber type more readily than would strip or line samples, and would have the advantage of being more permanent. Their main disadvantage would probably be that a considerable amount of ground work would be needed to establish boundary markers in areas where natural ground features were not sufficiently prominent to be usable. The maintenance or reestablishment of such markers from year to year would probably prove to be an added burden.

A



B

Figure 1. Fairchild vertical view finder. A - side view; B - top view showing ground glass screen. (from Bagley - Aerophotography and Aerosurveying. McGraw Hill Book Co., 1941)

The foregoing methods have a number of disadvantages that may eliminate them from practical consideration. First, they are here considered on the assumption that the ground level is perfectly flat, whereas in actuality it seldom is. Second, it is supposed here that the autogiro would be able to maintain a fairly uniform course parallel to the surface of the earth, whereas in practice this may be impossible. In the third place, records of this type depend entirely on the accuracy of the observer, and do not lend themselves readily to checking of any sort. The samples are transitory and cannot be retaken at a later date with any expectation of accuracy because of the progression of the loss and, in the case of the line and strip methods, the difficulty of retracing the flight course with sufficient exactness. Spotting records could not be used for detailed office studies, as for example direct measurements on trees, in the manner that photographic records could. Moreover, there would be no way of separating the loss on a yearly basis in counts made from the air unless it were possible to map the infested trees on a permanently marked area that could be reflown. The main advantage of spotting methods lies in their simplicity. It should be possible, with a small amount of equipment and a good flight plan, to detect an insect outbreak and obtain a rough estimate of the number of red-topped trees on an area. Perhaps this is about all that can be expected of aerial spotting.

Photographic Methods

Aerial photography for making maps has become almost a science in itself (Bagley, 1941; McKinley, 1929). The development of precision equipment has made it possible to reproduce the wealth of detail in small scale aerial photographs in the form of an accurate map (Talley, 1938; Whitmore, 1941). Thus new ways of solving old problems suggest themselves.

Two types of photographs are used for aerial map construction, viz., vertical photographs, taken with the optical axis of the camera lens perpendicular to the surface of the earth, and obliques, which are taken with the optical axis of the camera lens at an angle of about 30 degrees below the horizontal. Vertical photographs are generally used for ordinary aerial maps, since the reproduction of the photographic detail in map form is much less complicated with verticals than with obliques. Obliques are useful in studying vertical dimensions of objects, and in interpreting detail not distinguishable in vertical photographs. Their use for map construction is limited by the fact that they cannot be accurately scaled, and because their distortion from perspective is increased.

Thus far little has been done in this country by way of using vertical aerial photographs of segments of forested areas as samples of the stand. This may be due to the fact that the data obtainable from the ordinary photograph may not readily lend itself to the needs of forest management, although this explanation is not supported by Braithwaite's (1940) success in applying photographic technique to forest management problems. The difficulty of distinguishing tree species, crown dimensions, and stand density in the usual small scale vertical photograph may have been considered insurmountable, although recent work by Ryker (1933) indicates that these problems may eventually be mastered. By reason of the fact that with panchromatic film and filters it is possible to take photographs of stands that distinctly show the differences between green and insect-killed trees (Figure 2), the forest insect loss survey problem should be ideal for a study of forest sampling by aerial photographic methods. The chief modification that would be needed in the photographic technique for this kind of a study would be to greatly increase the scale of the pictures. Instead of pictures on a scale 1:10,000 or 1:24,000, pictures on a scale of 1:2500 or larger would be needed. (Figure 3). On a scale this large it would be possible to make direct measurements of the dimensions of the trees themselves. Height measurements in plain vertical pictures would be out of the question, except as they might be derived from shadow measurements, or through photogrammetric measurements on stereo pairs (Andrews, 1936). However, crown diameter and density of stocking could be obtained. The known relationship between crown diameter and stem diameter suggests possibilities for eventually deriving volume estimates of loss per acre from crown measurements alone. Another desirable objective that may be possible with aerial photographs is the securing of loss records on an annual basis. If sample areas could be photographed periodically, this information could be obtained by a comparison of the pictures.

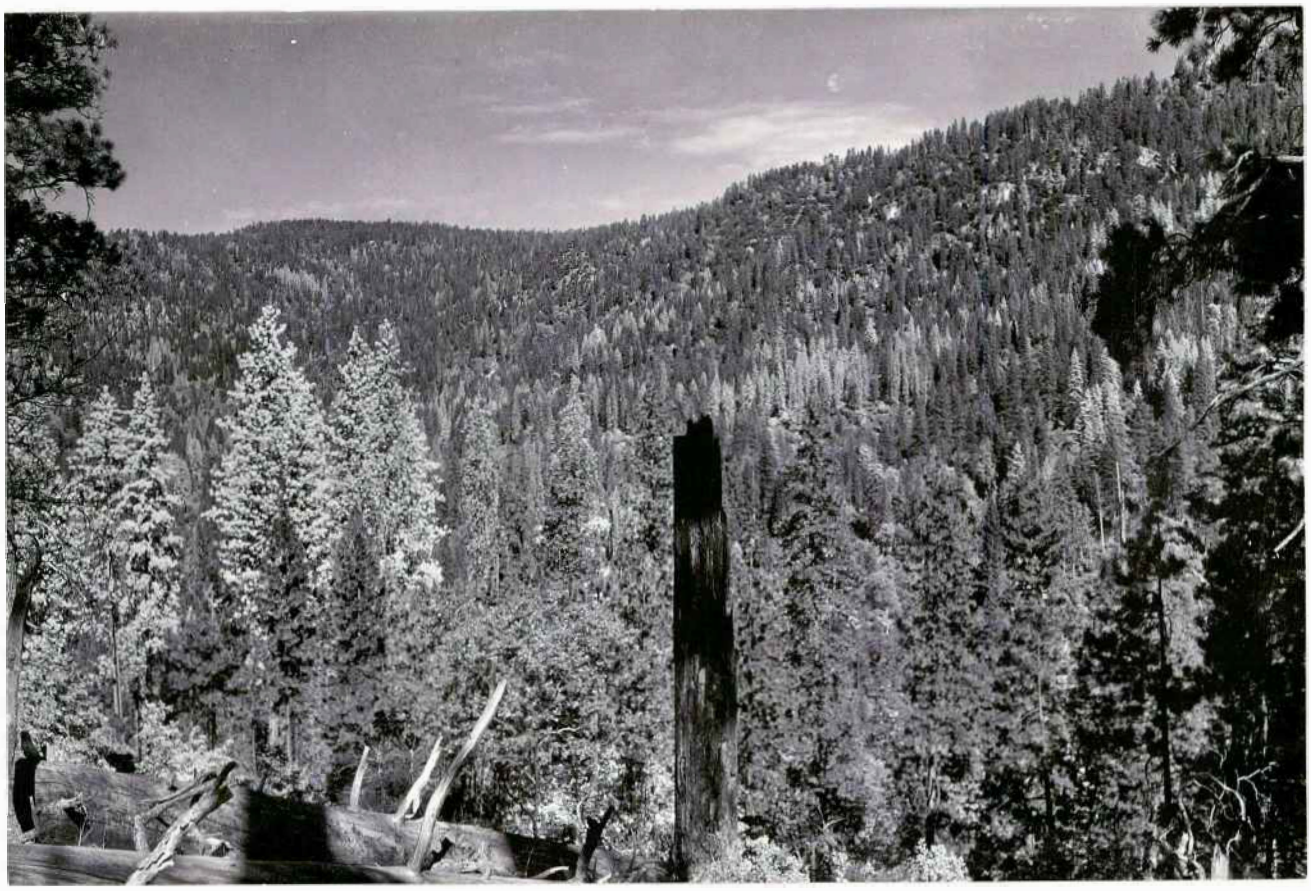


Figure 2. An illustration of what can be done with panchromatic film and a red filter to show red trees in a heavily infested stand. (Photo by J. M. Miller)

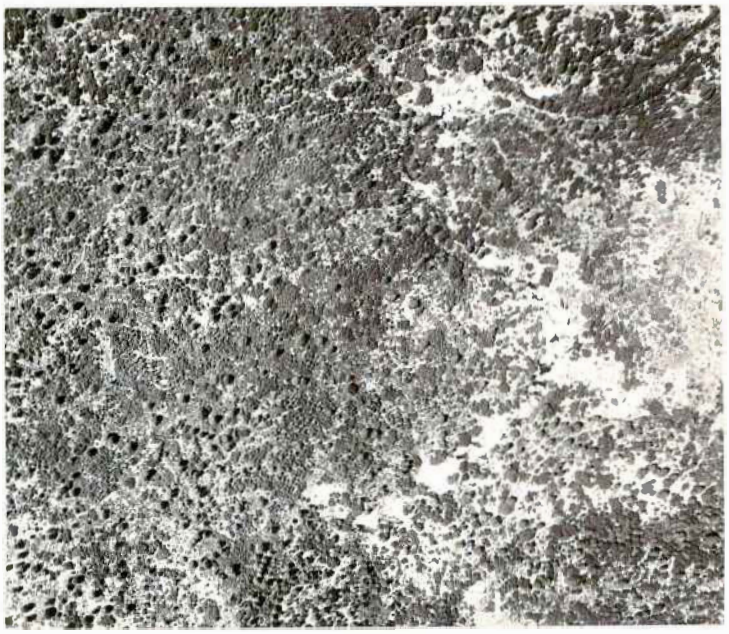


Photo by U. S. Army Air Service
A

Photo by F. P. Keen
B

Figure 3. Comparison of aerial photographs of different scales. A - Conventional photograph, scale 1:10,000. B - Type of photograph necessary for forest insect survey, scale 1:2,500.

VERTICAL PHOTOGRAPHS FOR FOREST INSECT LOSS SURVEYS

The equipment requirements and preliminary preparations for a forest insect loss survey utilizing vertical photographs would have to be much more elaborate than similar preparations where spotting methods were to be used. Certain requisites in the aerial camera, the airplane, and the ground preparations probably would have to be met. The following discussion, outlining the equipment and general procedure for this sort of a study, is based on the recommendations made in recent texts, previously cited, and published articles on aerial photography. (Seely, 1938; U.S. War Department, 1941 A, 1941 B) It should be kept in mind that in standard aerial photographic practice, pictures are taken on a scale much smaller than that which would be desirable for sample plot studies, and that actual tests may prove that the procedure usually employed in such work would have to be radically revised to meet this particular problem.

Equipment Requirements

Several types of aerial cameras, both single and multiple lens, and many kinds of planes are used for aerial mapping. For the forest insect loss survey a single lens camera should be satisfactory, since it would only be necessary to take single, vertical views of the forest. Mosaics or overlapped photographs would not be needed. No published record can be found of an autogiro having been used as a photographic ship; however, if it meets the requirements of other planes used for photographic purposes, it should be satisfactory. Moreover, its ability to fly at a very slow speed should be quite an advantage in taking large scale photographs.

The Camera

The camera should be of the type customarily employed for vertical photography. It should have a non-collapsible bellows, and should be equipped with a good lens, rigidly set at fixed focus. It should be set in a vibrationless mount that may be fastened to the floor of the plane, and should have both level bubbles and a view finder.

Single lens aerial cameras are usually equipped with lenses varying in focal length from 8¼ to 24 inches. A lens having a focal length of 6 to 8 inches should be satisfactory for the use contemplated in this study. The scale needed for sample plot pictures (1:2500) is great enough so that the image formed by a lens of this size should be satisfactory in size and definition. The lens speed should not be less than f.4.5. All types of aerial mapping cameras

used in this country are equipped with between-the-lens shutters. The use of focal plane shutter is generally prohibited in taking aerial photographs intended for mapping purposes. The reason for this is that while the focal plane shutter may give the sharpest image, the length of time necessary for the slit in the curtain to pass by the film may be so great in relation to the speed of the plane as to present considerable distortion of the view. This limitation of the focal plane shutter would apply to the present study just as well as it does to aerial mapping.

Commercial roll film is used in nearly all aerial cameras, although one or two makes are equipped for glass plates. Roll film is stable enough so that shrinkage is not a serious problem. Tests have shown that the differental change between length and width over three and one-half years averages 0.02 percent. In photographic mapping special aerial film nine inches wide and up to several hundred feet in length, is used. This film is only available for aerial cameras, and cannot be obtained in ordinary sizes. Panchromatic emulsions have been found far superior to orthochromatic emulsions because of their speed and latitude. For photographing red-topped trees, the panchromatic film would be essential.

The type of filter recommended for aerial photography is a gelatin disc cemented between optical glass and mounted in front of the lens. Filters should be selected so that exposures can be made at the medium apertures since poor definition results from the use of the larger apertures. Wratten dyed red filters with a factor of 4 or 8 are recommended for securing the best results in aerial mapping. From the work that has been done in ground studies, there is little question but that at least a C and preferably an A filter would be necessary for photographing insect-killed trees.

The Plane

The plane should be capable of operating at a slow speed, and be able to maneuver at elevations of 6,000 to 8,000 feet above sea level. It should have sufficient power so that it may be flown with a reasonable degree of safety over roughterritory at fairly low heights above the forest canopy. To meet the need of vertical aerial photography it should have an opening in the floor with a view unobstructed by landing gear, braces, etc. A floor space of 4 by 6 feet within the plane is usually required to handle standard aerial cameras and accessory equipment. A somewhat smaller space than this, depending on the camera equipment used, should be sufficient for the equipment needed for the loss survey.

Preflight Preparations

Before the aerial work is begun a considerable amount of preliminary work is necessary both in the office and in the field. Preparations should be made to see that the area to be photographed will be well enough marked so that it may be recognized in the pictures. The approximate scale of the photographs must be decided upon, and the altitude of flight necessary to secure photographs with the desired scale should be computed. In addition, a flight map should be prepared, charting the course of flight for the pilot.

Ground Preparations

The ground preparations for routine aerial mapping are somewhat less complicated than those that would be needed for photographing sample plots from the air. On the usual aerial mapping job the features of the country are generally well enough defined in existing maps so that additional ground marking is not necessary. In sample plot studies, however, it is necessary to mark in some way the ground areas to be photographed. In some cases it may be possible to locate plots close to prominant topographic features. In other cases, as in an intensively managed, well-mapped area, such as an experimental forest, there may be an established road network complete enough so that additional ground marking would not be necessary. In most forested areas, however, a preliminary ground reconnaissance and marking would be needed.

Several methods for marking plots have been tried. In the woodlands of New England Potts (1939) used orange flags on the corners of ten-acre plots, and white flags down the center. The flags were attached to bamboo poles which in turn were fastened to the tops of trees. In the hardwood forests of New England where tree heights do not exceed 40 to 50 feet, Potts found this system practical. In the hemlock forests of southwestern Washington Keen (1931) found the flag system impractical. The difficulties and risk attendant to climbing trees in this region, where the average height of the forest canopy was nearly 150 feet, eliminated the method. In this same study an attempt was made to direct the flight lines by signals from ground observers located at the ends of the flight strips, 280 feet apart and 1 mile in length. This method had to be abandoned because the density of the undergrowth prevented the ground men from keeping up with the plane as it proceeded from strip to strip. Another method that has been suggested is to mark the plot corners by smoke signals at the time of flight. This is impractical for so many reasons that it is not worthy of further consideration here.

In the Modoc survey in 1927, Keen used ground markers made of newspapers weighted down with stones. These were very satisfactory, for the eastside ponderosa pine forests are characteristically open, and the markers were visible both from the plane and in the pictures. Lime, cloth, or possibly whitewashed or painted rocks could be substituted for newspapers if desired. In aerial surveys made by the Forest Service, a pyramidal, wooden frame covered with cloth is sometimes used for a ground marker. Cloth is good for one season only; however, plywood or masonite could be substituted for the cloth if a more permanent marker were needed. One advantage of markers laid out as geometric figures which is not associated with other types of plot markers is that they are useful after the field operations have been completed in computing the scale of the photographs.

Scale

It is necessary to decide upon the approximate scale of the final photograph before the flight is begun in order to compute the height at which the picture must be taken. The height may be calculated by the formula:

$$H = \frac{f}{s}$$

where H = height
f = focal length of camera
s = scale

The scale may also be determined by measuring directly on the print the image of an object on the ground of known actual length. The area covered in each picture may be calculated by converting the dimensions to feet and following through the usual calculations for computing the area of plane surfaces. The dimensions are converted by the following formula:

$$\frac{D}{f} \times H = \text{Distance in feet}$$

where D = dimension of prints in inches
f = focal length of lens in inches
H = height in feet

As already mentioned in an earlier section it would be highly desirable to take pictures on a fairly large scale to study conditions on small areas. The different sized areas that could be covered at different elevations with a 5 x 7 inch camera fitted with an 8 inch lens are listed in Table 1.

Table 1. Ground Area Covered at Different Elevations with a 5 by 7 inch Camera Equipped With an 8 inch Lens

Height	Width	Length	Area
200 feet	125.0 feet	175.0 feet	0.50 acre
300	187.5	262.5	1.13
400	250.0	350.0	2.01
500	312.5	437.5	3.13
750	468.75	656.25	7.06
1000	625.0	875.0	12.55
1500	937.5	1312.5	28.25
2000	1250.0	1750.0	50.21
2500	1562.5	2187.5	78.47
3000	1875.0	2625.0	112.99

A lens with a focal length of 7 inches is the shortest that will cover a 5 by 7 inch field. By using a lens of this length, the areas covered at the different elevations listed in the above table would be increased by approximately 30 percent. For example, the area of 12.55 acres covered by an 8 inch lens at 1000 feet would be increased to 16.39 acres with a 7 inch lens at the same elevation.

Altitude of flight

In order to photograph a 20-acre plot 12 by 16.67 chains with a 5 by 7 inch camera, it would be necessary to fly at a height of 1,250 feet above the ground level. To make certain that the entire acreage of the plot was included in the picture, this height should be increased to 1500 feet. At this height the photograph would cover, with an 8-inch lens, an area of 28 acres; with a 7-inch lens, an area of 37 acres.

The ordinary altimeter indicates the elevation above sea level. Special equipment has been invented to give the height in relation to ground level, but very few planes are equipped with it. For photographing forest sample plots, it would be necessary to determine the elevation of the plots from existing maps, and increase this elevation by the height at which it is desired to take the pictures.

The Flight Map

For the purpose of guiding the pilot the course of the flight should be plotted on a map of country to be flown. In sample plot work it would be advantageous to indicate on the map the position of the plots, so that the pilot may make a special effort to have the ship at the proper elevation and on an even keel at the time the pictures are taken. This, of course, presupposes that the pilot is capable of reading and understanding a map and that the plane is slow enough and powerful enough to be flown on a predetermined course at fairly low elevations. In aerial mapping the lines of flight are usually started at some easily recognizable topographic feature, and terminated in the same manner. In plot photography a similar procedure would be necessary. In test studies, however, the markings of ground plots should prove to be of considerable help in guiding the route of the pilot.

Flight Requirements for Best Photographs

The flights should be planned to take advantage of optimum lighting conditions in order to secure the best results. Uniform lighting is obtained only when there are no clouds, or when the sky is completely overcast. Photographs taken under an overcast sky are comparable to ground pictures taken under the same lighting. They lack contrast and are dull to look at, but they may be satisfactory for the study of details. Pictures should not be attempted when there is a heavy ground fog or smoke between the camera and the subject. It would be advisable to make use of Weather Bureau forecasts in planning flights from day to day. For best results the taking of vertical pictures is usually avoided when the sun is below 30°, although this is not always possible in the northern latitudes. The recommended flying hours for verticals are between 10 A.M. and 2 P.M.

Procedure for Taking Pictures

There are but two parts to the procedure of taking the pictures, once all the preliminaries have been taken care of. A preliminary run is made over the area to be photographed in order to locate the ground reference points. This is followed by the photographic run in which the exposures are made.

The length of exposure can only be determined by experience. It is affected in aerial photography by the same factors as in ordinary photography. The basic exposure recommended for taking verticals for mapping the average terrain is 1/100 of a second. Forested areas are said to require 1½ to 2 times as much exposure. Due to the difference in sample plot photography, as compared with photographic mapping, it will probably be advisable to determine the basic exposure by a series of test exposures in the field.

OBLIQUE PHOTOGRAPHS FOR FOREST INSECT LOSS SURVEYS

Oblique aerial photographs differ from verticals in that they are taken over the side of the plane with the camera purposely tilted at an angle from the horizontal. This procedure results in a rectangular picture that represents an area having the shape of a trapezoid. Oblique photographs that include the horizon are called high obliques, whereas those taken with the camera depressed 30 degrees from the horizontal are termed low obliques. As pointed out in previous discussion, the usefulness of oblique photographs is limited by the fact that the distances in the scene involved cannot be accurately scaled. However, according to Wilcox (1936) the use of transparent grids drawn in perspective upon celluloid or lumarith will enable the user to determine the scale of an oblique, providing the distance between two identifiable features in the photograph is known. The scale determined by this method is as accurate as the measurement upon which its determination is based.

In an oblique photograph the features of a scene may be more easily recognized than in a vertical, since the viewpoint is similar to that of an observer stationed on a high point of land or on a lookout. The scene is viewed partly in the horizontal and partly in the vertical plane, instead of being viewed in just the one or the other. This is a distinct advantage in picking out insect-killed trees in an oblique photograph, which is not shared by the vertical. When insect-killed trees are photographed from directly above, particularly at a high elevation, their forms may blend into the surroundings so well that their presence may easily escape detection (Figure 3A). When photographed at a steep angle, however, if the color of the tree is such that it blends with its surroundings, its form may be sufficiently distinct to prevent it from being entirely overlooked (Figure 3B). This fact may warrant some experimentation with large-scale oblique photographs for recording insect-caused loss in forested areas. If the photographs were taken at an extremely steep angle so as to prevent the blanking out of trees occurring in groups by trees in the foreground, the resulting pictures would have many of the characteristics common to both the vertical and the oblique. At the present time it is not possible to carry this discussion much beyond the stage of conjecture, since so little has been done with steep obliques for the purpose under consideration.

The various phases of the field procedure for vertical photographs, described in the preceding pages of this report, should be equally applicable to the taking of obliques. A slow aircraft and a 5 by 7 inch, single lens camera that could be operated over the side of the cockpit would be needed. Likewise preliminary ground preparations preceding the photographic flight and the problems attendent thereto would probably be similar for both types of photographs. Lighting will be a more important factor in the taking of oblique photographs, for disregard of lighting altogether may result in little other than silhouettes of the trees, where it would not be possible to distinguish green from red foliage. With the direction and angle of lighting properly accounted for in relation to the direction from which the picture is taken, it should be possible to secure highlight and shadow detail not obtainable in photographing from directly above.

Extremely steep obliques taken a short distance above the forest canopy may be suitable for making direct measurements on the trees. Such a procedure has proven effective in Canada (Seely, 1938) where special forest inventory photographs have been taken with the camera depressed 40 degrees from the horizontal. The inventory photographs are taken on orthochromatic film during the winter season when the snow blanket is present on the ground to furnish maximum contrast between the trees and their surroundings. Volumetric estimates are obtained by determining the average height of the dominant and co-dominant trees, establishing a volume per acre figure by the use of intensity curves, and adjusting the volume per acre by degree of density and percent of hardwoods present. Certain of these procedures might be adapted to an aerial survey of insect-killed timber.

PROPOSALS FOR TESTING AIRCRAFT FOR FOREST INSECT LOSS SURVEYS

From the reports of men who have attempted forest insect surveys from the air, it appears that the autogiro is the most satisfactory ship to use in further tests. Its slow cruising speed should prove to be an outstanding advantage in testing spotting or photographic survey methods from the air, and its ability to land and take off from small fields should make it less dangerous to operate in mountainous country than the regular plane. In the light of Miller's and Keen's experiences with airplanes in California, it is doubtful if it would be worthwhile to continue experiments with aircraft with minimum safe flying speeds as high as 75 or 80 miles per hour. However, with a slow ship like the autogro, it might be possible to develop, with a series of carefully planned tests, new and useful techniques for making the annual insect loss surveys. By no means the least consideration in this matter is the fact that the Bureau already owns and operates several autogiros on the east coast.

Objectives

It is suggested that tests be set up to find answers to the following questions:

1. Can insect-killed trees be spotted from the air with the same degree of accuracy as from the ground?

2. What is the cost differential in covering the same area by aerial and by ground methods?

3. What is the difference in the time element for aerial versus ground methods?

4. Can photographic methods be employed to obtain annual loss data?

5. What information cannot be obtained from the air that can be obtained from the ground?

Areas

It is proposed that the following areas be used as testing grounds: (1) Eastern Plumas National Forest, and (2) Black's Mountain Experimental Forest. These areas are suggested by reason of the fact that the former is representative of areas covered by the usual survey methods utilizing plots, roadstrips, and reconnaissance, whereas the Black's Mountain area is annually covered by a 100 percent survey, and thus would be useful for checking the accuracy of aerial methods. Both of these areas still have appreciable infestations, and there are enough bug trees present to make the aerial tests. In addition, both areas may be easily reached daily from the Susanville airport.

Time of Survey

It is suggested that tests of some of the ideas advanced in the earlier pages of this memorandum be made a season's project to be undertaken at such a time as the necessary equipment is available. The equipment needed is an autogiro, with a competent pilot and mechanic, and an aerial camera. A major phase of the project would be to prepare a detailed working plan, outlining as far as possible the procedure for getting satisfactory answers to the problem. Preparation of such a plan and completion of the necessary ground work would call for the services of two men for the better part of a season.

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